J. Raptor Res. 35(3):259–262

DIET AND BREEDING SUCCESS OF EAGLE OWL IN SOUTHEASTERN SPAIN: EFFECT OF RABBIT HAEMORRHAGIC DISEASE

JOSÉ E. MARTÍNEZ AND JOSÉ F. CALVO
Departamento de Ecología e Hidrología, Facultad de Biología, Universidad de Murcia, Campus de Espinardo, 30100 Espinardo (Murcia), Spain

KEY WORDS: *Eagle Owl;* Bubo bubo; *rabbit disease; Spain; abandoned territories; breeding success; diet.*

Food is one of the main factors influencing the breeding biology and population ecology of raptors (Newton 1979). Several studies have documented numerical and functional responses in breeding populations resulting from changes in prey abundance (Korpimäki and Norrdahl 1991, Rohner 1996, Redpath and Thirgood 1999, Nielsen 1999). In generalist raptor species, individuals can respond to prey declines by remaining in nesting territories without reproducing (Southern 1970, Smith et al. 1981, Korpimäki et al. 1990), shifting their diet composition (Steenhof and Kochert 1988), or reducing their brood size (Viñuela and Veiga 1992, Houston and Schmutz 1995, Steenhof et al. 1997).

Rabbits (*Oryctolagus cuniculus*) are the main prey for many predators in European Mediterranean ecosystems including Eagle Owls (*Bubo bubo*) (Delibes and Hiraldo 1981, Rogers et al. 1994), but how changes in rabbit populations affect the diet and reproductive success of predators has been poorly studied (Viñuela and Veiga 1992). In areas where rabbits are scarce, Eagle Owls have been reported to prey on small mammals, especially rodents (Donázar et al. 1989).

Since 1988, a new viral disease, rabbit haemorrhagic disease (RHD), has affected rabbit populations in the Mediterranean area (Villafuerte et al. 1995). While the epizootic has been shown to affect the breeding success of Golden Eagles (*Aquila chrysaetos*) (Fernández 1993) and red foxes (*Vulpes vulpes*) (Villafuerte et al. 1996), little information is available on its effects on Eagle Owls. In this paper, we present evidence for the effect of RHD on the diet and breeding success of Eagle Owls in southeastern Spain.

STUDY AREA AND METHODS

Our study was conducted in a mountainous area (0–828 m) in the south of the Murcia Region (southeastern Spain) from 1987–91. The study area covered about 1300 km^2 and was characterized by an arid and semiarid Mediterranean climate (annual rainfall <350 mm). The Eagle Owl is fairly common in Murcia Region and the Iberian Peninsula (Díaz et al. 1996, Sánchez-Zapata 1999). In southern Murcia, rabbit is its staple food, representing up to 50% of the prey items (Martínez et al. 1992). RHD was first recorded in the study area in autumn 1988 (Rogers et al. 1994), when it reduced the rabbit population by 75% (Etisa 1990, M.A. Sánchez pers. comm.). A similar mortality rate was also observed in the first outbreak of the disease in other localities of southern Spain (Peiró and Seva 1990). Since then, there have been no other detectable changes in land use or food supply in the area, although other factors such as overhunting may have contributed to the decline in rabbit numbers (Fernández 1993). RHD reappears annually, mainly during spring and winter, but these outbreaks have not caused as great a mortality as the initial outbreak in 1988 (Etisa 1990, Villafuerte et al. 1995).

From 1987–91, we located occupied owl territories by searching for suitable owl nest sites, listening for elicited vocalizations using recorded calls, and listening to spontaneous vocalizations. We considered a territory to be vacant when no owls were sighted or heard, no occupied nests were located, or no fresh prey remains, pellets, or droppings were observed. When pairs were not recorded in traditional sites, we searched suitable breeding habitats within a radius of 3 km of the tradition site to exclude the possibility that they moved to a new breeding site To estimate the reproductive success of breeding pairs of owls, a minimum of three visits were made to each site to confirm egg-laying, successful reproduction, brood size at fledging (fledglings/successful pair), and productivity (number of young fledged/breeding pair).

The dietary analysis of Eagle Owls was based on a sample of 2026 prey items (1340 prey items before RHD and 686 prey items after RHD). Pellet contents were identified by macroscopic comparison with skeletal and skin reference collections. Prey remains and loose bones were omitted because they overestimate the occurrence of larger prey (Mersmann et al. 1992, Real 1996). We identified and counted each prey item using the most frequently found bone or feather to calculate the minimum number of individuals present (Olsson 1979). Pellets were obtained from nests after young fledged and from perch sites outside the breeding season. During the period December–March, no collections were made because females were incubating.

To compare yearly breeding parameters with the owl diet before and after the RHD outbreak, Kruskal-Wallis tests were used (Sokal and Rohlf 1969). We used a Chi-square test to assess differences in nest site occupancy before and after RHD. Statistical analyses were perfomed with STATISTIX (Analytical Software 1992).

Table 1. Annual changes in breeding success of the Eagle Owl before (1987–88) and after (1989–91) rabbit haemorrhagic disease (RHD).

YEAR	PAIRS	VACANT TERRITORIES	LAYING PAIRS	SUCCESSFUL PAIRS	PRODUCTIVITY	FLEDGING SUCCESS
Before RHD						
1987	19	0	12	11	1.57	2.72
1988	19	0	17	14	2.36	3.21
After RHD						
1989	17	0	7	7	0.94	2.28
1990	8	11	5	5	1.12	1.80
1991	9	10	8	8	1.55	1.75

RESULTS AND DISCUSSION

After the RHD epidemic, both the brood size and young fledged per breeding pair decreased significantly (H = 0.5942, P = 0.0034 and H = 25.6471, $P < 0.001$, respectively) (Table 1). The number of laying pairs and the number of successful pairs after RHD did not show significant variation. Before the occurrence of RHD, all the Eagle Owl nesting territories were regularly occupied whereas, after RHD, there was a significant decrease in occupancy (χ^2 = 18.74, $P < 0.001$).

Rabbits were the main prey consumed by Eagle Owls during the overall period analyzed, but after the RHD outbreak, the proportion of rabbits in the diet decreased slightly (from 55.97% to 53.64%) (Table 2). Also, the proportion of alternative prey (e.g., *Rattus* spp.) in the diet before and after RHD did not differ significantly (from 15.75% to 24.49%). However, after RHD the proportion of pigeons (*Columba* spp.) and other mammals in the diet decreased significantly (H = 4.0102, P = 0.0441 and H = 12.1708, $P < 0.001$, respectively).

After the outbreak of RHD, rabbits remained the principal prey of Eagle Owls despite the crash in rabbit densities and the fact that consumption of alternative prey species did not increase. Our findings differed from those of Fernández (1993) and Mañosa (1994) who found dietary shifts following the decrease in the rabbit population caused by the viral haemorrhagic disease. The owls in our study may not have shown a functional response switching prey species because there was an increase in the availability of sick rabbits in spring and summer and/or alternative prey species were not available. Several authors have suggested that diseases such as RHD and myxomatosis facilitate the capture of rabbits by predators (Viñuela and Veiga 1992, Fernán-

Table 2. Comparison of the diet of Eagle Owls before and after rabbit haemorrhagic disease (RHD). The number (N) and proportions (%) of prey found in pellets as well as the Kruskal-Wallis statistic (H) are indicated.

TAXON	BEFORE RHD (1987–88) N	BEFORE RHD (1987–88) %	AFTER RHD (1989–91) N	AFTER RHD (1989–91) %	H
Mammals	1078	80.4	592	86.3	
Rabbits	750	56.0	368	53.6	0.0494 (NS)[1]
Rats	211	15.7	168	24.5	2.4214 (NS)
Small mammals	24	1.8	8	1.2	2.2171 (NS)
Hedgehogs	79	5.9	47	6.8	3.1598 (NS)
Other mammals	14	1.0	1	0.1	12.1708***
Birds	262	19.5	94	13.7	
Galliformes	41	3.1	17	2.5	0.6753 (NS)
Columbidae	41	3.1	10	1.5	4.0102*
Corvidae	27	2.0	7	1.0	1.7138 (NS)
Birds of prey	40	3.0	19	2.8	0.5346 (NS)
Other birds	113	8.4	41	6.0	1.8100 (NS)
Total	1340		686		

[1] NS = not significant; * $P < 0.05$; *** $P < 0.001$.

dez 1993, Villafuerte et al. 1996, Villafuerte and Viñuela 1999).

Nesting productivity decreased after RHD indicating that the crash in the rabbit population negatively affected the breeding success of Eagle Owls. Sharp declines in food resources during the breeding season have a marked negative influence on the breeding success of predators (Steenhof and Kochert 1988, Fernández 1993, Villafuerte et al. 1996, Steenhof et al. 1997), especially if the predator cannot find alternative prey (Korpimäki et al. 1990). After RHD, the number of territorial pairs laying eggs and the number of laying pairs that were successful were lower indicating that the decrease in rabbits negatively affected the fecundity of Eagle Owls. Several authors have suggested that rabbit availability determines the number of pairs of Eagle Owls that begin breeding (Olsson 1979, Mikkola 1983, Donázar 1990, Serrano 2001); nevertheless, it was clear from our findings that this species can still breed when its main prey decreases. However, we are unclear as to the minimum rabbit density which causes Eagle Owls to cease breeding.

We found that the number of occupied nesting territories after RHD decreased by 50%, probably due to the virtual disapperance of rabbits. Our findings concurred with previous studies that have found rabbit scarcity to have caused the extinction of Eagle Owls in Mediterranean localities (Donázar and Ceballos 1984, Serrano 1998). Nevertheless, they contrasted with numerous other studies which found that most species of raptors remain on nesting territories but do not lay eggs during periods of low prey abundance (Southern 1970, Saurola 1989, Fernández 1993, Steenhof et al. 1997). Because pairs can continue to occupy territories but not start breeding during periods of low prey density making their presence difficult to detect, we may have failed to locate some pairs that continued to occupy nesting territories after RHD. Consequently, our comments should be taken cautiously.

RESÚMEN.—Estudiamos el efecto de la neumonía vírica del Conejo (NHV) sobre la dieta y el éxito reproductor en una población de Búho Real (*Bubo bubo*) del sureste de España. El conejo (*Oryctolagus cuniculus*) y las ratas (*Rattus* spp.) fueron las presas más importantes en la dieta. Después de la neumonía hemorrágica del conejo, no se observaron cambios en el consumo de conejo y ratas. La proporción de conejo en la dieta del Búho Real no fue afectada por el cambio de densidad de conejo, quizás debido a la mayor accesibilidad de los individuos enfermos durante la epizootia. La drástica reducción de las poblaciones de conejo condujo a una fuerte disminución de la productividad y la tasa de vuelo del Búho Real. El número de parejas reproductoras disminuyó drasticamente después de la NHV, y la mayoría de las parejas no fueron detectadas. Sospechamos que este hecho pudiera estar relacionado con el abandono de las zonas de nidificación por parte del Búho Real, debido a la fuerte disminución de la población de conejo y a una simultánea escasez de presas alternativas.

[Traducción de autores]

ACKNOWLEDGMENTS

J.A. Martínez, A. Izquierdo, M. Carrete, L.L. Vizcaíno, V. Penteriani, and S. Fabrizio kindly made many valuable recommendations for which we are most grateful.

LITERATURE CITED

ANALYTICAL SOFTWARE. 1992. Statistix version 4.0. user's manual. St. Paul, MN U.S.A.

DELIBES, M. AND F. HIRALDO. 1981. The rabbit as prey in the Iberian Mediterranean ecosystem. Pages 614–622 *in* K. Myers and C.D. McInnes [EDS.], Proc. world lagomorph conf. (1979). Univ. Guelph, Guelph, ON Canada.

DÍAZ, M., B. ASENSIO, AND J.L. TELLERÍA. 1996. Aves ibéricas. Vol. I. No Passeriformes. Editorial J.M. Reyero, Madrid, Spain.

DONÁZAR, J.A. 1990. Geographic variation in clutch and brood size of the Eagle Owl *Bubo bubo* in the Western Palearctic. *J. Ornithol.* 131:439–443.

——— AND O. CEBALLOS. 1984. Algunos datos sobre status, distribución y alimentación del búho real (*Bubo bubo*) en Navarra. *Rapinyaires Mediterranis* 2:246–254.

———, F. HIRALDO, M. DELIBES, AND R.R. ESTRELLA. 1989. Comparative food habits of the Eagle Owl *Bubo bubo* and the Great Horned Owl *Bubo virginianus* in six Palearctic and Nearctic biomes. *Ornis Scand.* 20:298–306.

ETISA, S.L. 1990. Plan de aprovechamiento cinegético de la Región de Murcia. Agencia Regional para el Medio Ambiente y la Naturaleza, Murcia, Spain.

FERNÁNDEZ, C. 1993. Effect of the viral haemorrhagic pneumonia of the wild rabbit on the diet and breeding success of the Golden Eagle *Aquila chrysäetos* (L.). *Rev. Ecol. Terre Vie* 48:323–329.

HOUSTON, C.S. AND J.K. SCHMUTZ. 1995. Declining reproduction among Swainson's Hawks in prairie Canada. *J. Raptor Res.* 29:198–201.

KORPIMÄKI, E. AND K. NORRDAHL. 1991. Numerical and functional responses of kestrels, Short-eared Owls, and Long-eared Owls to vole densities. *Ecology* 72:814–826.

———, K. HUHTALA, AND S. SULKAVA. 1990. Does the year-to-year variation in the diet of Eagle and Ural Owls support the alternative prey hypothesis?. *Oikos* 58:47–54.

MAÑOSA, S. 1994. Goshawk diet in a Mediterranean area of northeastern Spain. *J. Raptor Res.* 28:84–92.

MARTÍNEZ, J.E., M.A. SÁNCHEZ, D. CARMONA, J.A. SÁNCHEZ, A. ORTUÑO, AND R. MARTÍNEZ. 1992. Ecology and conservation of the Eagle Owl *Bubo bubo* in Murcia, southeast Spain. Pages 84–88 *in* C.A. Galbraith, I.R. Taylor, and S. Percival [EDS.], The ecology and conservation of European owls. U.K. Nature Conservation No. 5

Peterborough Joint Nature Conservation Committee, Peterborough, U.K.

MERSMANN, T.J., D.A. BUEHLER, J.D. FRASER, AND J.K.D. SEEGAR. 1992. Assessing biases in studies of Bald Eagle food habits. *J. Wildl. Manage.* 56:73–78.

MIKKOLA, H. 1983. Owls of Europe. T. and A.D. Poyser Ltd., Calton, U.K.

NEWTON, I. 1979. Population ecology of raptors. T. and A.D. Poyser Ltd., Calton, U.K.

NIELSEN, Ó.K. 1999. Gryfalcon predation on ptarmigan: numerical and functional responses. *J. Anim. Ecol.* 68: 1034–1050.

OLSSON, V. 1979. Studies on a population of Eagle Owls. *Viltrevy* 11:1–99.

PEIRÓ, V. AND E. SEVA. 1990. Le lapin de garenne dans la province d'Alicante (sud-est de l'Espagne). *Bull. Mens. Off. Nat. Chase* 182:189–196.

REAL, J. 1996. Biases in diet study methods in the Bonelli's Eagle. *J. Wildl. Manage.* 60:632–638.

REDPATH, S.M. AND S.J. THIRGOOD. 1999. Numerical and functional responses in generalist predators: Hen Harriers and peregrines on Scottish grouse moors. *J. Anim. Ecol.* 68:879–892.

ROGERS, P.M., C.P. ARTHUR, AND R.C. SORIGUER. 1994. The rabbit in continental Europe. Pages 22–63 *in* H.V. Thompson and C.M. King [EDS.], The European rabbit: history and biology of a successful colonizer. Oxford Univ. Press, Oxford, U.K.

ROHNER, C. 1996. The numerical response of Great Horned Owls to the snowshoe hare cycle: consequences of non-territorial floaters on demography. *J. Anim. Ecol.* 65:359–370.

SÁNCHEZ-ZAPATA, J.A. 1999. Las aves rapaces y su relación con la estructura del paisaje en ambientes mediterráneos semiáridos. Tesis Doctoral, Universidad de Murcia, Spain.

SAUROLA, P. 1989. Breeding strategy of the Ural Owl *Strix uralensis.* Pages 235–240 *in* B.-U. Meyburg and R.D. Chancellor [EDS.], Raptors in the modern world. World Working Group for Birds of Prey, Berlin, Germany.

SERRANO, D. 1998. Diferencias interhábitat en la alimentación del Búho Real (*Bubo bubo*) en el valle medio del Ebro (NE de España): efecto de la disponibilidad de conejo (*Oryctolagus cuniculus*). *Ardeola* 45:35–46.

———. 2001. Parámetros reproductivos y fecha de puesta del Búho Real (*Bubo bubo*) en el Valle del Ebro. *Rocín, Anuario Ornitológico de Aragón* 1998–1999. In press.

SMITH, D.G., J.R. MURPHY, AND N.D. WOFFINDEN. 1981. Relationships between jackrabbit abundance and Ferruginous Hawk reproduction. *Condor* 83:52–56.

SOKAL, R.R. AND F.J. ROHLF. 1969. Biometry. W.H. Freeman and Co., San Francisco, CA U.S.A.

SOUTHERN, H.N. 1970. The natural control of a population of Tawny Owls (*Strix aluco*). *J. Zool. (Lond.)* 162: 197–285.

STEENHOF, K. AND M.N. KOCHERT. 1988. Dietary responses of three raptor species to changing prey densities in a natural environment. *J. Anim. Ecol.* 57:37–48.

———, ———, AND T.L. MCDONALD. 1997. Interactive effects of prey and weather on Golden Eagle reproduction. *J. Anim. Ecol.* 66:350–362.

VILLAFUERTE, R. AND J. VIÑUELA. 1999. Size of rabbits consumed by Black Kites increased after a rabbit epizootic. *Mammal Rev.* 29:261–264.

———, C. CALVETE, J.C. BLANCO, AND J. LUCIENTES. 1995 Incidence of viral haemorrhagic disease in wild rabbit populations in Spain. *Mammalia* 59:651–659.

———, D.F. LUCO, C. GORTÁZAR, AND J.C. BLANCO. 1996. Effect on red fox litter size and diet after rabbit haemorrhagic disease in north-eastern Spain. *J. Zool. (Lond.)* 240:764–767.

VIÑUELA, J. AND J.P. VEIGA. 1992. Importance of rabbits in the diet and reproductive success of Black Kites in southwestern Spain. *Ornis Scand.* 23:132–138.

Received 30 December 2000; accepted 19 May 2001